oceanography, engineering, or physics. For example, hydrometeorology is the blending of hydrology (the science of Earth's water) and meteorology, and is the field concerned with the effect of precipitation on the hydrologic cycle and the environment. Students who wish to become broadcast meteorologists for radio or television stations should develop excellent communication skills through courses in speech, journalism, and related fields. Those interested in air quality work should take courses in chemistry and supplement their technical training with coursework in policy or government affairs.

Beginning atmospheric scientists often do routine data collection, computation, or analysis, and some basic forecasting. Entry-level operational meteorologists in the Federal Government are usually placed in intern positions for training and experience. During this period, they learn about the Weather Service's forecasting equipment and procedures, and rotate to different offices to learn about various weather systems. After completing the training period, they are assigned a permanent duty station. Experienced meteorologists may advance to supervisory or administrative jobs, or may handle more complex forecasting jobs. After several years of experience, some meteorologists establish their own weather consulting services.

The American Meteorological Society offers professional certification of consulting meteorologists, administered by a Board of Certified Consulting Meteorologists. Applicants must meet formal education requirements (though not necessarily have a college degree), pass an examination to demonstrate thorough meteorological knowledge, have a minimum of 5 years of experience or a combination of experience plus an advanced degree, and provide character references from fellow professionals.

Job Outlook

Employment of atmospheric scientists is projected to increase about as fast as the average for all occupations through 2008, and prospective atmospheric scientists may face competition if the number of degrees awarded in atmospheric science and meteorology remain near current levels. The National Weather Service (NWS) has completed an extensive modernization of its weather forecasting equipment and finished all hiring of meteorologists needed to staff the upgraded stations. The NWS has no plans to increase the number of weather stations or the number of meteorologists in existing stations for many years. Employment of meteorologists in other Federal agencies is expected to decline slightly as the Federal Government attempts to balance its budget.

On the other hand, job opportunities for atmospheric scientists in private industry are expected to be better than in the Federal Government over the 1998-2008 period. As research leads to continuing improvements in weather forecasting, demand should grow for private weather consulting firms to provide more detailed information than has formerly been available, especially to weather-sensitive industries. Farmers, commodity investors, radio and television stations, and utilities, transportation, and construction firms can greatly benefit from additional weather information more closely targeted to their needs than the general information provided by the National Weather Service. Additionally, research on seasonal and other long-range forecasting is yielding positive results, which should spur demand for more atmospheric scientists to interpret these forecasts and advise weather-sensitive industries. However, because many customers for private weather services are in industries sensitive to fluctuations in the economy, the sales and growth of private weather services depend on the health of the economy.

There will continue to be demand for atmospheric scientists to analyze and monitor the dispersion of pollutants into the air to ensure compliance with Federal environmental regulations outlined in the Clean Air Act of 1990, but employment increases are expected to be small.

Earnings

Median annual earnings of atmospheric scientists in 1998 were $54,430. The middle 50 percent earned between $38,570 and $75,260. The lowest 10 percent earned less than $27,250 and the highest 10 percent earned more than $87,760.

The average salary for meteorologists in nonsupervisory, supervisory, and managerial positions employed by the Federal Government was about $62,500 in 1999. Meteorologists in the Federal Government with a bachelor's degree and no experience received a starting salary of $20,600 or $25,500, depending on their college grades. Those with a master's degree could start at $25,500 or $31,200; those with the Ph.D., at $37,700 or $45,200. Beginning salaries for all degree levels are slightly higher in selected areas of the country where the prevailing local pay level is higher.

Related Occupations

Workers in other occupations concerned with the physical environment include oceanographers, geologists and geophysicists, hydrologists, physicists, mathematicians, and civil, chemical, and environmental engineers.

Sources of Additional Information

Information about careers in meteorology is available from:

☛ American Meteorological Society, 45 Beacon St., Boston, MA 02108. Internet: **http://www.ametsoc.org/AMS**

Information on acquiring a job as a meteorologist with the Federal Government may be obtained from the Office of Personnel Management through a telephone-based system. Consult your telephone directory under U.S. Government for a local number or call (912) 757-3000 (TDD 912 744-2299). That number is not toll-free and charges may result. Information also is available from their Internet site: **http://www.usajobs.opm.gov**

Chemists

(O*NET 24105)

Significant Points

- A bachelor's degree in chemistry or a related discipline is usually the minimum educational requirement; however, many research jobs require a Ph.D.
- Job growth will be concentrated in drug manufacturing and research and testing services firms.

Nature of the Work

Everything in the environment, whether naturally occurring or of human design, is composed of chemicals. Chemists search for and put to use new knowledge about chemicals. Chemical research has led to the discovery and development of new and improved synthetic fibers, paints, adhesives, drugs, cosmetics, electronic components, lubricants, and thousands of other products. Chemists also develop processes that save energy and reduce pollution, such as improved oil refining and petrochemical processing methods. Research on the chemistry of living things spurs advances in medicine, agriculture, food processing, and other fields.

Chemists apply their knowledge of chemistry in various ways. Many work in research and development (R&D). In basic research, chemists investigate properties, composition, and structure of matter and the laws that govern the combination of elements and reactions of substances. In applied research and development, they create new products and processes or improve existing ones, often using knowledge gained from basic research. For example, synthetic rubber and plastics resulted from research on small molecules

uniting to form large ones, a process called polymerization. R&D chemists use computers and a wide variety of sophisticated laboratory instrumentation. The use of computers to analyze complex data allows chemists to practice combinatorial chemistry. This technique makes and tests large quantities of chemical compounds simultaneously in order to find compounds with desired properties. Combinatorial chemistry makes chemists more productive by saving time and materials and could result in more products being developed in the future. They also spend time documenting and analyzing the results of their work and writing formal reports.

Chemists also work in production and quality control in chemical manufacturing plants. They prepare instructions for plant workers that specify ingredients, mixing times, and temperatures for each stage in the process. They also monitor automated processes to ensure proper product yield, and they test samples of raw materials or finished products to ensure they meet industry and government standards, including the regulations governing pollution. Chemists record and report on test results, and improve existing or develop new test methods.

Chemists often specialize in a subfield. *Analytical chemists* determine the structure, composition, and nature of substances by examining and identifying the various elements or compounds that make up a substance. They study the relations and interactions of the parts and develop analytical techniques. They also identify the presence and concentration of chemical pollutants in air, water, and soil. *Organic chemists* study the chemistry of the vast number of carbon compounds that make up all living things. Organic chemists who synthesize elements or simple compounds to create new compounds or substances that have different properties and applications have developed many commercial products, such as drugs, plastics, and elastomers (elastic substances similar to rubber). *Inorganic chemists* study compounds consisting mainly of elements other than carbon, such as those in electronic components. *Physical chemists* study the physical characteristics of atoms and molecules and investigate how chemical reactions work. Their research may result in new and better energy sources.

Biochemists, whose work encompasses both biology and chemistry, are included in the statement on biological scientists elsewhere in the *Handbook*.

Chemists hold bachelor's, master's, and doctoral degrees.

Working Conditions

Chemists usually work regular hours in offices and laboratories. Research chemists spend much time in laboratories, but also work in offices when they do theoretical research or plan, record, and report on their lab research. Although some laboratories are small, others are large enough to incorporate prototype chemical manufacturing facilities as well as advanced equipment. Chemists do some of their work in a chemical plant or outdoors—while gathering water samples to test for pollutants, for example. Some chemists are exposed to health or safety hazards when handling certain chemicals, but there is little risk if proper procedures are followed.

Employment

Chemists held about 96,000 jobs in 1998. Nearly half of chemists are employed in manufacturing firms—mostly in the chemical manufacturing industry, which includes firms that produce plastics and synthetic materials, drugs, soaps and cleaners, paints, industrial organic chemicals, and other miscellaneous chemical products. Chemists also work for State and local governments, and for Federal agencies. Health and Human Services, which includes the Food and Drug Administration, the National Institutes of Health, and the Center for Disease Control, is the major Federal employer of chemists. The Departments of Defense and Agriculture, and the Environmental Protection Agency, also employ chemists. Other chemists work for research, development, and testing services. In addition, thousands of persons held chemistry faculty positions in colleges and universities. (See the statement on college and university faculty elsewhere in the *Handbook*.)

Chemists are employed in all parts of the country, but they are mainly concentrated in large industrial areas.

Training, Other Qualifications, and Advancement

A bachelor's degree in chemistry or a related discipline is usually the minimum educational requirement for entry-level chemist jobs. However, many research jobs require a Ph.D.

Many colleges and universities offer a bachelor's degree program in chemistry, about 620 of which are approved by the American Chemical Society (ACS). Several hundred colleges and universities also offer advanced degree programs in chemistry; around 320 master's programs, and about 190 doctoral programs are ACS-approved.

Students planning careers as chemists should take courses in science and mathematics, and should like working with their hands building scientific apparatus and performing experiments. Perseverance, curiosity, and the ability to concentrate on detail and to work independently are essential. In addition to required courses in analytical, inorganic, organic, and physical chemistry, undergraduate chemistry majors usually study biological sciences, mathematics, and physics. Those interested in the environmental field should also take courses in environmental studies and become familiar with current legislation and regulations. Computer courses are essential, as employers increasingly prefer job applicants who are able to apply computer skills to modeling and simulation tasks and operate computerized laboratory equipment.

Because research and development chemists are increasingly expected to work on interdisciplinary teams, some understanding of other disciplines, including business and marketing or economics, is desirable, along with leadership ability and good oral and written communication skills. Experience, either in academic laboratories or through internships or co-op programs in industry, also is useful. Some employers of research chemists, particularly in the pharmaceutical industry, prefer to hire individuals with several years of postdoctoral experience.

Graduate students typically specialize in a subfield of chemistry, such as analytical chemistry or polymer chemistry, depending on their interests and the kind of work they wish to do. For example, those interested in doing drug research in the pharmaceutical industry usually develop a strong background in synthetic organic chemistry. However, students normally need not specialize at the undergraduate level. In fact, undergraduates who are broadly trained have more flexibility when job hunting or changing jobs than if they narrowly define their interests. Most employers provide new graduates additional training or education.

In government or industry, beginning chemists with a bachelor's degree work in quality control, analytical testing, or assist senior chemists in research and development laboratories. Many employers prefer chemists with a Ph.D. or at least a master's degree to lead basic and applied research. A Ph.D. is also often preferred for advancement to many administrative positions.

Job Outlook

Employment of chemists is expected to grow about as fast as the average for all occupations through 2008. Job growth will be concentrated in drug manufacturing and research, development, and testing services firms. The chemical industry, the major employer of chemists, should face continued demand for goods such as new and better pharmaceuticals and personal care products, as well as more specialty chemicals designed to address specific problems or applications. To meet these demands, chemical firms will continue to devote money to research and development—through in-house teams or outside contractors—spurring employment growth of chemists.

Within the chemical industry, job opportunities are expected to be most plentiful in pharmaceutical and biotechnology firms. Stronger competition among drug companies and an aging population are contributing to the need for innovative and improved drugs discovered through scientific research. Chemical firms that develop and manufacture personal products such as toiletries and cosmetics must continually innovate and develop new and better products to remain competitive. Additionally, as the population grows and becomes better informed, the demand for different or improved grooming products—including vegetable-based products, products with milder formulas, treatments for aging skin, and products that have been developed using more benign chemical processes than in the past—will remain strong, spurring the need for chemists.

In most of the remaining segments of the chemical industry, employment growth is expected to decline as companies downsize and turn to outside contractors to provide specialized services. Nevertheless, some job openings will result from the need to replace chemists who retire or otherwise leave the labor force. Quality control will continue to be an important issue in the chemical and other industries that use chemicals in their manufacturing processes. Chemists will also be needed to develop and improve the technologies and processes used to produce chemicals for all purposes, and to monitor and measure air and water pollutants to ensure compliance with local, State, and Federal environmental regulations.

Outside the chemical industry, firms that provide research, development, and testing services are expected to be the source of numerous job opportunities between 1998 and 2008. Chemical companies, including drug manufacturers, are increasingly turning to these services to perform specialized research and other work formerly done by in-house chemists. Chemists will also be needed to work in research and testing firms that focus on environmental testing and cleanup.

During periods of economic recession, layoffs of chemists may occur—especially in the industrial chemicals industry. This industry provides many of the raw materials to the auto manufacturing and construction industries, both of which are vulnerable to temporary slowdowns during recessions.

Earnings

Median annual earnings of chemists in 1998 were $46,220. The middle 50 percent earned between $34,580 and $68,360. The lowest 10 percent earned less than $27,240 and the highest 10 percent earned more than $86,260. Median annual earnings in the industries employing the largest numbers of chemists in 1997 were:

Federal Government	$62,800
Drugs	43,300
Research and testing services	34,500

A survey by the American Chemical Society reports that the median salary of all their members with a bachelor's degree was $50,100 a year in 1999; with a master's degree, $61,000; and with a Ph.D., $76,000. Median salaries were highest for those working in private industry; those in academia earned the least. According to an ACS survey of recent graduates, inexperienced chemistry graduates with a bachelor's degree earned a median starting salary of $29,500 in 1998; with a master's degree, $38,500; and with a Ph.D., $59,300. Among bachelor's degree graduates, those who had completed internships or had other work experience while in school commanded the highest starting salaries.

In 1999, chemists in nonsupervisory, supervisory, and managerial positions in the Federal Government earned an average salary of $64,200.

Related Occupations

The work of chemical engineers, agricultural scientists, biological scientists, and chemical technicians is closely related to the work done by chemists. The work of other physical and life science occupations, such as physicists and medical scientists, may also be similar to that of chemists.

Sources of Additional Information

General information on career opportunities and earnings for chemists is available from:

☛ American Chemical Society, Education Division, 1155 16th St. NW., Washington, DC 20036. Internet: **http://www.acs.org**

Information on acquiring a job as a chemist with the Federal Government may be obtained from the Office of Personnel Management through a telephone-based system. Consult your telephone directory under U.S. Government for a local number or call (912) 757-3000; TDD (912) 744-2299. That number is not toll free and charges may result. Information also is available from their Internet site: **http://www.usajobs.opm.gov**

Geologists, Geophysicists, and Oceanographers

(O*NET 24111A and 24111B)

Significant Points

- Work at remote field sites is common.
- A bachelor's degree in geology or geophysics is adequate for entry-level jobs; better jobs with good advancement potential usually require at least a master's degree. A Ph.D. degree is required for most research positions in colleges and universities and in government.